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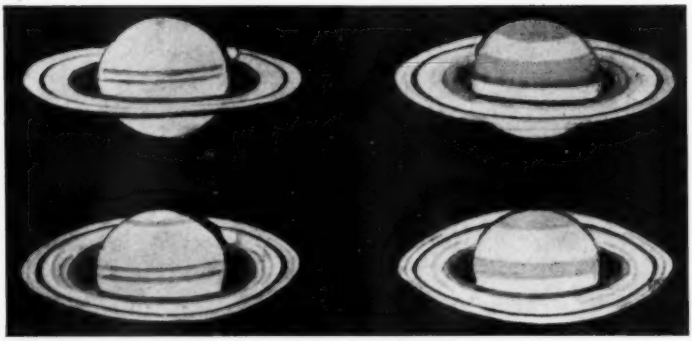
PLATE I



DRAWINGS OF SATURN

Upper Left—W. H. Haas; 12-inch rfr. at 200x; 3 h. 49 m. on November 28, 1939; conditions rather poor.

Upper Right—H. M. Johnson; 8-inch rfl. at 213x; 4 hr. 28 m. on October 13, 1940; conditions fairly good.

Lower Left—W. H. Haas; 18-inch rfr. at 300x; 22 h. 47 m. on February 3, 1942; conditions fairly good.

Lower Right—E. K. White; 9-inch rfl. at 250x and 300x; 3 h. 38 m. on December 7, 1942; Conditions fair. [This drawing is not intended to show any shading or division in Ring B, the middle ring.]

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OBSERVATIONS OF SATURN, 1939-43

By WALTER H. HAAS

(With Plate I)

THIS paper will report on observations of Saturn made by a small group of amateurs chiefly between June 17, 1939, and April 27, 1943. (Universal Time is employed as the basis of dates and times throughout this paper.) The data thus relate to four different apparitions at each of which the planet was followed for from nine to ten months. The dates of opposition are October 22, 1939; November 3, 1940; November 17, 1941; and December 1, 1942. The oppositional declination of the planet increased from +8° in 1939 to +20° in 1942 so that it was well placed for northern observers. The oppositional value of B, the Saturnicentric latitude of the earth, increased numerically from −15° in 1939 to −26° in 1942; the rings were hence opened well at the beginning of this period and almost to the maximum extent attained at its end. The planet was drawn only occasionally; a few typical views are reproduced in Plate I.

The co-operating observers are as follows:

Name	*Telescope*	*Station*	*Remarks*
Barcroft, D. P.	6-in. refl.	Madera, Calif.	
Barker, R.	12-in. refl.	Cheshunt, Herts., England	
Cave, T. R.	10-in. refl.	Long Beach, Calif.	
Cyrus, C. M.	10-in. refl.	Lynchburg, Virginia	
Gramm, C. F.	4-in. refr.	Rochester, New York	
Haas, W. H.	8-in. refl.	Des Moines, Iowa	Johnson's telescope
"	two 6-in. refls.	New Waterford, Ohio	
"	12-in. refr.	Columbus, Ohio	O.S.U. Observatory
"	18-in. refr.	Upper Darby, Penna.	Flower Observatory
Johnson, H. M.	8-in. refl.	Des Moines, Iowa	
"	6-in. refl.	Rochester, New York	R. T. Smith's telescope

Name	*Telescope*	*Station*	*Remarks*
Johnson, H. M.	7-in. refl.	Rochester, New York	Vaughn's telescope
"	18-in. refr.	Upper Darby, Penna.	Observed with Haas
Vaughn, F. R.	8-in. refl.	Des Moines, Iowa	
"	7-in. refl.	Rochester, New York	
"	18-in. refr.	Upper Darby, Penna.	Observed with Haas
"	9-in. refl.	Plainfield, New Jersey	
White, E. K.	9-in. refl.	Chapman Camp, B.C., Canada	
Wilson, L. J.	12-in. refl.	Nashville, Tennessee	Chiefly photographic

An outstanding feature of Saturn is its lack of much observable change. The same aspects present themselves with monotonous regularity. Probably a casual observer using a small telescope would have noted no physical changes (as apart from geometric ones) during the four apparitions herein reviewed.

There were regularly seen two dark belts not far from the middle of the ball; these we shall call the S.E.B.$_N$ and the S.E.B.$_S$ (south equatorial belt, north and south components). I measured seven drawings to obtain their Saturnian latitudes β and found the S.E.B.$_N$ to be at β—17°, the S.E.B.$_S$ at β—28°. To Vaughn and me these belts exhibited a perhaps variable red tone. Johnson called them perhaps brown; White, gray. The S.E.B.$_N$ was darker than the S.E.B.$_S$. Some of the descriptive remarks above really relate only to the first three of the apparitions herein considered. Between April and August of 1942 a change occurred. During the 1942-3 apparition the components of the belt were less easy to separate than before, it usually being uncertain whether the S.E.B. was single or duplicate; the belt was occasionally surprisingly light; and the S.E.B.$_N$ was no longer regularly darker than its neighbour. These altered aspects are demonstrated by good observational evidence. Under good conditions I have seen, with a number of different telescopes, numerous *difficult* condensations and rifts in each belt. Barker and Cave have also observed this delicate internal detail. Vaughn, Johnson, and apparently Barcroft followed a very faint condensation in the S.E.B.$_S$ in 1940 (1). Barker drew a notable enlargement in the S.E.B.$_S$ on February 19, 1942; J. Metzger of Philadelphia, Penn., had recorded an apparently very similar mark 36 days earlier with a six-inch reflector. Perhaps they remarked two transient objects, for on neighboring dates I saw

nothing similar. On October 1 and 4, 1942, I observed a faint dark projection at the south edge of the S.E.B. In September-December 1942 Vaughn and I perceived a large number of small humps on the north edge of the S.E.B.. Wilson wrote that *the original* of a photograph taken by him on November 19, 1941, shows the north edge of the S.E.B. to be irregular.

The space between the north edge of the S.E.B.$_s$ and the south edge of the dark projection of the Crape Ring on the ball we shall call the E.Z. (equatorial zone). It was regularly the brightest part of the ball, being brighter than Ring A but duller than the duller inner half of Ring B. Its colour was white to Johnson, Vaughn, and me. It was almost of uniform brightness, and any markings in it were very delicate.

The ball south of the S.E.B.$_s$ was dull, being about equal to Ring A in this respect. Johnson *suspected* several very faint belts in this region in 1940. Near the south limb was a dark south polar shading, bounded at its north edge by a faint dark belt. Vaughn described the shading as gray. Perhaps the shading grew slowly fainter and the belt slowly stronger from 1939 to 1943; at any rate I thought the belt darker than before in April 1943. I measured five drawings for the latitude of this belt and found it to be at β—73°.

The Saturnian belt-system is very stable and inactive compared to the Jovian. It is true that following a particular Saturnian belt from year to year is often prevented by the earth's changing Saturnicentric latitude or by the related fact that the rings usually conceal part of the ball. It appears significant, though, that in observing Saturn from 1935 to 1943 the only well-evidenced changes in the belts which I have found are a prominence of a belt near β—5° for a short time near June 1936; an increased conspicuousness of the S.E.B.$_s$ from 1939 to 1943 as compared to its aspect from 1936 to 1938; and the recent change in the S.E.B. region described above.

When marks conspicuous enough for their transits across the central meridian of the planet to be timed exist, it is important to observe such transits in order to determine rotation-periods (2). Only in the S.E.B. has our group detected marks plain enough for such efforts. Johnson has derived an average rotation-period of 10 hours 19.3 min. for a *very* vague condensation near β—18° followed by him

and others from September 14 to October 30, 1940. Late in 1941 Cave obtained some transits, but it is not possible to derive any worthwhile periods from that part of his work which is known to me. In 1942 I succeeded in obtaining 14 transits of two small humps on the north edge of the S.E.B.$_N$*. Each hump was followed from September 7 to October 7. Saturnian transit-observers are urged to emulate me in trying to observe successive transits of a few marks rather than scattered transits of many individually poorly followed marks. Assuming an arbitrary zero meridian of longitude and an approximately correct period of rotation, I computed the longitude Y for the date X of each observation. No corrections were applied for the change in the phase of the planet or in its direction from the earth during the period of observation; the maximum error in Saturnian longitude caused by these omissions was less than half a degree. Allowance was made for the more significant change in light-time as Saturn neared the earth. For each hump a Least Squares Line of the form $Y' = a + bX$ was then computed. The slopes b of these lines supplied the most probable corrections to the period assumed above. The period of one hump came out to be $10^h17^m53^s$; that of the other, $10^h17^m36^s$. To alter either of these periods by as much as five seconds would lead to inadmissible discrepancies in the observations. Using the measured latitude of the centre of the S.E.B.$_N$ as a basis for prediction, I should say that these two marks were near $\beta - 13°$. Since our group has now observed Saturnian transits at four successive apparitions, it appears worthwhile to suggest that such work is regularly possible. The marks that must usually be used are assuredly delicate, but suitable programmes undertaken by experienced observers equipped with good telescopes might shed much light on Saturnian currents.

The dusky Crape Ring was readily seen all the way around (except behind the planet) by at least seven of the observers. When the rings are opened well it is so visible in a six-inch reflector of any worth, and the much-repeated statements about its delicateness must be described as absurd. This ring was most outstanding where projected against the bright ball, and this dark projection appeared to me to contain *delicate* darker condensations and to lack a smoothly elliptical inner

*In August-September 1943 I observed transits of a number of tiny humps at this position.

edge. Vaughn once confirmed the condensations with the 18-inch refractor. I regularly noted a dark copper-red hue in this ring, but White called it gray.

The observers agree that Ring B was much brighter than Ring A. Vaughn, White, Johnson, and I found B brightest at its outer edge and dullest at its inner edge, though even the inner edge surpassed the average brightness of A. The brightness of B probably altered by steps rather than continuously. Vaughn, Johnson, and I thought this ring white.

What may well be called a third division in the rings (in addition to Cassini's and Encke's) has been observed near the inner edge of Ring B. Johnson drew a shading here with an 8-inch reflector on October 13, 1940. I saw such a shading with the 18-inch from October 1941 to January 1942. On January 17, 1942, I viewed Saturn to good advantage with this telescope on a twilight sky, and the supposed shading was now seen to be a division; i.e., it was concentric with the inner edge of B, and a strip of bright ring separated it from that edge. I reported my finding to Vaughn, who informed others in the group. Once "discovered," this third division was clearly and usually visible to me in the 18-inch; and its character was easily recognized with a 6-inch reflector. Barker in good seeing saw it with complete certainty on February 19, 1942. During the 1942-3 apparition Vaughn saw it plainly with a 9-inch reflector and an 18-inch refractor. Cyrus observed it only as a shading in fair seeing; and White looked vainly for it, even in fairly good seeing. During the 1942-3 apparition Vaughn and I agreed that it was plainer than Encke's Division, but Johnson and White saw Encke's without seeing this division. The three observers who have recorded the third division agree that it is far less black than Cassini's. The average of 11 visual estimates which I made places the third division at 0.18 ± 0.01 (probable error of mean) of the way from the inner edge of Ring B to the outer. Nine visual estimates by me make it six-fifths as wide as Cassini's; Vaughn once found it as wide as Cassini's; Barker insists that it is at least five-thirds as wide as Cassini's. Barker called the third rusty brown, but the others apparently saw only gray.

What may suitably be called a fourth division in the rings perhaps lies near the middle of Ring B and is more difficult than Encke's or

the third. I have observed it with the 18-inch only, first suspecting it on January 29, 1942. I have seen it with certainty only four times; on one of these occasions Vaughn independently recorded this feature with the same telescope. White suspected this mark once in November 1942, but later could not see it. Vaughn and I thought this division very faint, far lighter than Encke's or the third. I placed it at about three-fifths of the way from the inner edge of B to the outer; White agreed that it was closer to the outer edge than to the inner; Vaughn described it as near the middle of the ring. White spoke of it as extremely narrow; Vaughn, as about as wide as Encke's; I, as rather more than half as wide as Cassini's.

It is pertinent to ask whether these two divisions in Ring B are genuine and whether they have always existed. Aided by experience gained during eight years of visual lunar and planetary studies, I should opine that between the autumn of 1941 and the spring of 1943 the third was real and stable in appearance, the fourth, perhaps so, but that the darknesses and widths ascribed to them above must be viewed with caution. More observations of both divisions are needed. A widely opened condition of the rings, an experienced and attentive observer, and a good telescope at least eight inches in aperture are all prerequisite to the effective observation of these features. The work of past students of the planet is contradictory as regards possible divisions in Ring B. Some observers have seen none such even under excellent conditions. Lowell was perhaps the most successful; during the 1914-5 apparition he drew seven very narrow divisions in Ring B(3)*, but none of them is certainly identifiable with our third or fourth. However, a drawing by Lowell on February 6, 1912 (7), shows only one division in Ring B; this division is thin and light and agrees in position with our third. In 1899 Antoniadi drew a fine and "well marked" division near the middle of B (4), perhaps our fourth. Jarry-Desloges writes of seeing *two* narrow divisions near the inner ansae of this ring with the Meudon 33-inch. (5) Published drawings by such skilled observers as Phillips, Antoniadi, and Denning show

*The drawing in question shows two very narrow divisions in Ring A at the place where many observers see a single, wider, less black band, namely, Encke's Division. Is Lowell in error, and may his double canals on Mars be due to the operation of some similar source of possible illusion?

a *shading* at the inner edge of B (4); our recent experiences suggest that they were seeing the third division imperfectly. Barker writes that this division has been seen in England by several observers in the past.

Though not too easily traced in front of the ball during the 1939-40 and 1940-1 apparitions, Cassini's Division was subsequently clearly visible all the way around the rings to all observers reporting on it as a sharp and black gap. Late in 1942 Cyrus, Vaughn, and I saw Cassini's to widen into a wedge-shaped notch where it touched the limb of Saturn; this notch was fixed in position and doubtless illusory.

With the 18-inch I saw Ring A to be slightly but distinctly brighter outside Encke's than inside it. Cyrus and Vaughn compatibly comment on a difference in the brightness of A on opposite sides of Encke's. In September-November 1942, I recorded confidently that this ring was brighter than during the 1941-2 apparition, when it had been viewed with the same telescope. On December 22, 1942, I saw for the first time a pure white annulus just outside Cassini's and about two-thirds as wide as that gap. This annulus was still present on April 23, 1943, though perhaps it had grown fainter in the interim. By December 24, 1942, Barker had independently noted the inner edge of A to be very bright. I do not think that such an aspect existed in 1941-2. White could not affirm the annulus early in 1943 in poor seeing. Vaughn described Ring A as bluish or purplish; Johnson once thought it approximately amber; I regarded it as a dulled white.

Whatever may have been true in the past, Encke's Division existed during the last three of the apparitions herein reviewed. (It was not seen in 1939-40, presumably because the rings were then less widely opened.) In the 18-inch I observed it for perhaps 60° at each ansa whenever the seeing was not bad, and I once suspected it with a 6-inch reflector in excellent seeing. Barker and White have recorded Encke's with their telescopes. Cyrus has suspected it in his 10-inch reflector and once saw it plainly in the 18-inch. Vaughn has remarked it with 7- and 8-inch reflectors and with the 18-inch refractor. Johnson has done the same. Very surprising is the fact that Vaughn's 7-inch revealed Encke's to Gramm, *who was not previously familiar with this feature of the Saturnian system.* White, Johnson, Barker, and I think that Encke's is faint and no black gap like Cassini's; but Vaughn has

variously recorded it "as a very narrow *black* line, as a narrow darkish line, and as a broad dark line." Johnson, Vaughn, White, and I agree that this division is near the middle of A; eight visual estimates by me make it 0.56 ± 0.01 of the way from the inner edge of A to the outer, but White placed it slightly *inside* the middle. White described it as one-fourth to one-half as wide as Cassini's; Johnson found it much narrower than that gap; I thought it about four-fifths as wide as Cassini's; Vaughn obtained varying results, but usually it looked notably narrow to him. Vaughn thinks that his varying impressions are due to actual changes in the division. My own work is opposed to any such changes in 1941-2 and 1942-3.

Johnson has already reported the early results obtained by our group on a curious white spot in the rings adjacent to the shadow of the ball (6). Observations by him and me near the 1940, 1941, and 1942 oppositions have revealed that there are really *two white spots*, one on each ansa of the rings. These two spots are then about equally conspicuous; farther from opposition, one of them is concealed behind the planet. I have found either spot (usually just one is seen) to be regularly and about equally easily visible in the various telescopes that I have turned on Saturn. Johnson also found the unconcealed spot to be regularly present, but he considered it less plain in an 18-inch refractor than in reflectors of apertures from five to eight inches. Vaughn has recorded the unhidden spot with an 8-inch reflector, and Gramm has perceived it with ease in a 4-inch refractor; but White has looked vainly for it with a 9-inch reflector, nor has Barcroft seen it clearly with a 6-inch reflector. Johnson and I have often described either spot as "very plain." To him the spots are fairly distinctly bounded, but to me they look very diffusely outlined. Although they have shown some anomalies in their behaviour, their appearance for the most part has been singularly independent of changes in the seeing, the transparency, and the brightness of the sky. The observers differed badly about the size of the spots; Vaughn and I made either spot usually about five-halves as large as the adjacent shadow, Johnson, only one-half as large. The effect of irradiation would be to increase the size of a white spot relative to a black shadow. A study of my 40 size-estimates revealed a *notable* increase in the *relative* size of either spot as Saturn becomes close to opposition and a definite

increase when the planet nears conjunction. It appears permissible tentatively to conclude that the area of each spot is constant. Johnson's observations support such a result.

More observational work on these spots is much needed, and it is especially important to examine them critically near opposition. The prevailing and natural explanation that they are due to contrast with the black shadow can scarcely be maintained now that each spot has been seen near opposition on an unshadowed ansa of the rings. Swift's suggestion that they are due to sunlight reflected from the globe of Saturn (6) appears attractive. If so, they present a problem interesting and important to the theoretical student of planetary atmospheres. A test of Swift's explanation is that Saturnian and Jovian (if we may safely impute to Jupiter's atmosphere the properties of Saturn's) satellites should experience an anomalous brightening when at the edge of the shadow-cone of their respective primaries. Only precise photometry could discover such brightenings. It is worthwhile to mention Eropkin's results (8): after Jupiter I, Jupiter II, and Jupiter III have been decreasing in brightness as they near the shadow of Jupiter, they become constant in light or even brighten slightly for a number of minutes just before immersion.

The shadow of the rings on the ball was readily seen north of the rings during the 1939-40 apparition when the Saturnicentric latitude B′ of the sun numerically exceeded that of the earth, known as B. This shadow was *far* darker than the dark projection of the Crape Ring on the ball, being so black that one could easily appreciate why it was once asserted that only a solid surface could cast such a shadow. During the 1940-1 apparition the shadow was apparently less notable than in 1939-40, presumably because of its proximity to the north limb during the later apparition. It was not seen in 1941-2 and 1942-3 since little or nothing of the ball was then visible north of the widely opened rings. (When B numerically exceeded B′ the shadow of the rings on the ball was present south of the rings, but its detection was then rendered difficult by the superimposed Crape Ring.)

Except near opposition, the shadow of the ball on the rings was observed with the greatest ease. Nevertheless, its aspect at various times presented several anomalies which can hardly be regarded as other than optical illusions. One of these was a seemingly concave

outline to the shadow instead of the convex one demanded by the geometry of the system. I have frequently recorded a sharp angle in the shadow at Cassini's Division; Johnson, Cyrus, and Vaughn have also seen such an aspect. During the 1942-3 apparition, I regularly thought the shadow present on Ring B only and thus bounded by Cassini's Division, but computation shows that such was not its real limit. Perhaps the differing brightnesses of Rings A and B can account for at least part of these anomalies.

Since these two shadows vary in width from zero to quantities large enough to make them striking objects, it appeared worthwhile to attempt to use the observations made of them to ascertain how narrow a black band can be detected. The observations had unfortunately not been directed to this purpose; i.e., few efforts had been made to look specifically for either shadow when it was on the verge of disappearing or reappearing. The present study can hence supply only tentative results. It was first necessary to develop suitable mathematical methods, which cannot be detailed here for lack of space, for computing the breadth of each shadow to the hundredth of a second of arc. The narrowest width of the shadow of the rings (recorded only when north of the rings themselves) observed by us was 0″.18; I saw it thus on November 3, 1939, with a 12-inch refractor under poor conditions. In computing the width of the shadow of the ball it was necessary to decide just where in the rings this width should be measured; the place selected lay 1.8 polar radii of the planet from its centre and hence near the middle of Ring B. The width of this shadow, measured in a plane perpendicular to the line of sight, was defined to be the least possible distance from a point on the edge of the shadow to that one point which is observed to lie both on the limb of the planet and in the rings at the selected distance from the centre of Saturn. Investigation showed that our group always saw this shadow when its width (as just defined) was 0″.16 or more but never saw it when its width was 0″.12 or less. The width of 0″.16 was recorded by me on November 27, 1941, in poor seeing with the 18-inch. At breadths exceeding 0″.2 the shadow is plain and unmistakable. Coming to negative observations, we find that on November 16, 1941, a shadow of width 0″.02 was not visible to either Johnson or me in the 18-inch under fair conditions; probably so narrow a band

is effectively undetectable, except perhaps in the largest telescopes. On December 9 and 7, 1942, White did not see shadows of widths 0″.12 and 0″.08 respectively, and on November 28 in that year I failed to observe a shadow of breadth 0″.06; but these three negative observations were all made in poor seeing. Our tentative conclusion must be that black bands of width 0″.16 are visible against bright backgrounds and that much thinner black bands may be discernible. It is pertinent to mention in this place that W. H. Pickering has reported that he could see clearly a line of width 0″.07 upon an artificial disc and has given his opinion that a much finer line can be detected upon a planet (9). It might be instructive to check his findings by attentive observations of the two Saturnian shadows; this procedure has the advantage that one therein deals with the visibility of detail under actual conditions of observation.

During the 1941-2 apparition the ellipse of the rings was nearly tangent to the south limb of the planet. Johnson on July 23, 1941, with an 8-inch reflector and I on October 12, 1941, with the 18-inch refractor, each in fairly good seeing, thought it exactly tangent; these observations are not discreditable since on each occasion the limb projected only 0″.02 above (south of) the rings. In July, 1941, I recorded the rings to project *very slightly* above the limb, as seen with a 6-inch reflector, when in reality the limb barely projected above the rings; perhaps the polar shading at the south limb, combined with the small aperture used, produced this false impression.

On March 15, 1943, I saw the phase of Saturn in the sense that the limb was noted to be slightly brighter than the terminator; the 18-inch was being used, and the phase-angle i was 5°.9. The phase of Jupiter is frequently and more easily observable in the same way. The visibility of the phase of Saturn near quadrature may be regarded as a test of telescopes of adequate light-grasp.

110 N. Madison Street,
Upper Darby, Pennsylvania.
October 9, 1943.

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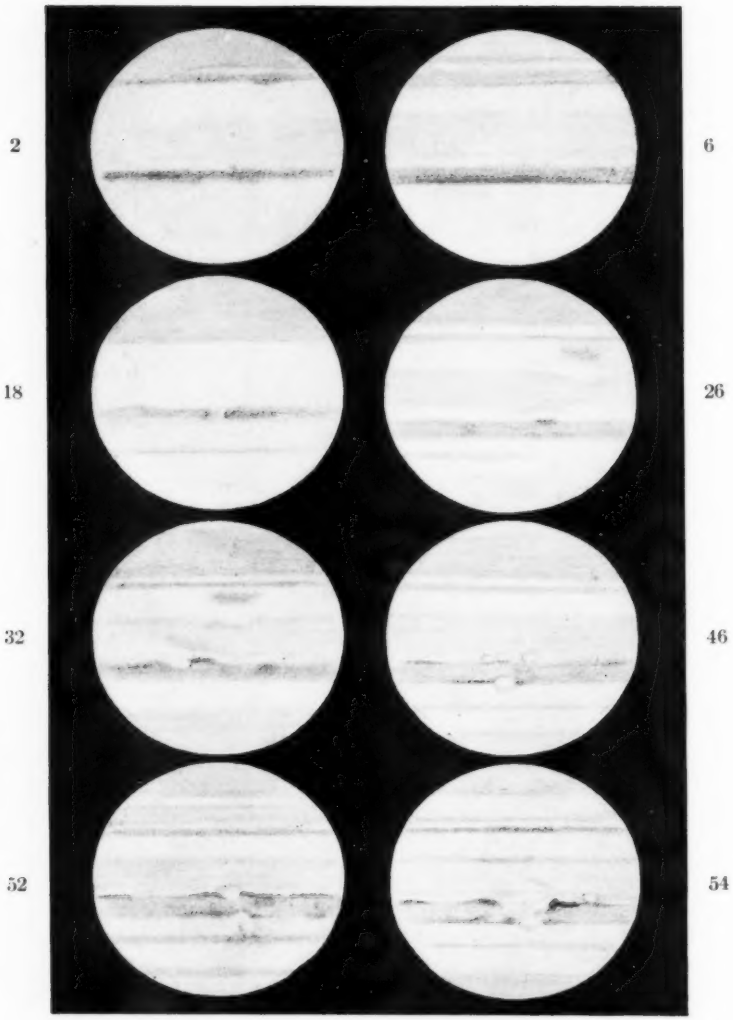
PLATE II



Drawings of Jupiter in 1937 by H. M. Johnson.

(*2*) May 31, 9:18, $312°_1$ $111°_2$, 7-in., 236X, 6. (6) June 11, 7:10, $173°_1$ $249°_2$, 7-in., 67X-236X, 7. (18) July 21, 3:45, $249°_1$ $21°_2$, 4¼-in., 177X, 7. (*26*) Aug. 12, 4:15, $143°_1$ $107°_2$, 7-in., 177X, 8. (32) Aug. 15, *2*:25, $190°_1$ $131°_2$, 5-in., 177X, 6. (46) Sep. 1, 4:20, $64°_1$ $235°_2$, 5-in., 177X, 6-7. (52) Sep. 12, *2*:38, $298°_1$ $26°_2$, 5-in., 236X, 7-8. (54) Sep. 16, 1:24, $164°_1$ $222°_2$, 5-in., 177X, 4-5. South at top.

THE TRAINING OF THE EYE IN VISUAL PLANETARY ASTRONOMY

By Hugh M. Johnson

(With Plate II)

THAT the ability of the telescopist to see detail on planetary images is in part simply a function of the time and alertness he gives to observing, is an opinion which apparently has been expressed by active observers, and which seems so well supported that it has not been openly contradicted, even by those who have not persevered to find whether in their case it is true or not. There are, indeed, several extra-astronomical analogies, such as the traditional special visual acuities of the woodsman, hunter, and mariner, developed in their respective fields. But it is suspected that there are some who do not realize how very pertinent this *training of the eye* is for success in visual observing, and astronomers, to my knowledge, have completely neglected any close investigation of just what may be expected of this training.

In this paper we may not hope to analyse the physiological and psychological principles which must be involved, nor may we determine whether the effect in question is wholly objective or partly only an illusional gain in skill; rather shall we confine attention to exposition of the results of a particular apparent manifestation of such training, thinking that it may be typical of what is said to occur generally. The prime source of this evidence is a series of drawings of the planet Jupiter which I made in 1937 under conditions which seem to be nearly ideal for revealing eye training. In 1936 I had made only a few planetary observations, including two drawings of Jupiter, and these with a reflector not quite 4 inches in aperture which indeed offered few details. Therefore in the following year, when I began regular observation with a larger telescope, it may be said that my ocular system was quite untrained. The drawings number 54, which is perhaps not quite the number of separate intervals on which Jupiter was examined during that apparition. Using U.T. as a basis of dates and times throughout, the first one came on May 23, the last on September 16, opposition being on July 15. The telescope was a Newtonian aluminized plate-glass reflector, 7-inch

primary of 59 inches focal length stationed at Des Moines, Iowa. This mirror until 1940 was strongly and not even regularly overcorrected and it was found from the beginning that a diaphragm of about 6¾ inches was needed, later that diaphragms down to less than 5 inches were probably helpful. But as the rectangular secondary mirror was too large, about 1¼ inch in the minor dimension, causing excessive diffraction, this telescope was never optimum. The training to be described therefore was accomplished with mediocre instrumental means; the question of its initial development with the best equipment must consequently remain unanswered.

Now it is true that other factors may enter into the amount of planetary detail resolved by a given observer and telescope. Primary among these is the variation in actual profusion of markings on the planet. If between May and September of 1937 Jupiter was increasing its display of detail at all comparably with my results, according to experienced observers, the results may not be attributed to eye training. We only mention here that the *Thirty-first Report of the Jupiter Section** of the British Astronomical Association fails to remark any increase of activity on the planet in 1937. The fact that sketching technique has much to do with what is recorded as distinct from what is seen is not forgotten, but in this case this technique had been advanced to a rather fixed point previous to the period of the present observations, so that all the drawings were made without further appreciable development in this way. I have attempted to control as much as possible other variables, such as seeing, in selecting eight of the 54 sketches for reproduction here. Every care has been given to make the copies of the originals faithful. Accompanying each drawing certain data are given in this order:—the chronological number of the drawing in the series, date, time, central meridians according to longitude systems I and II, aperture, magnification, and seeing. This last is on a scale of 0 (poorest) to 10 (best). The quotations in the following commentary are from the original observational notes.

No. (2) The N.E.B. has traces of irregularities in structure. The S.Temp.B. is second strongest, is with difficulty partially separated from the S.P.R. by the S.Temp.Z., and bears on its north edge a small condensation-

*B. M. Peek, *Memoirs of the B.A.A.*, vol. 35, part 1, p. 6, 1942.

enlargement which undoubtedly represents my first view of the Great Red Spot.

No. (6) shows the N.E.B. practically uniform and still only a barren expanse north of it. The S.Temp.B. is scarcely more than a northern boundary for the dark "south polar cap"; to its south lies a "rift" which I took to be the S.S.Temp.Z. though it is probably the S.Temp.Z. despite its narrowness and distance from the S.Temp.B.

No. (18) is the first drawing of the series portraying the N.Temp.B. In addition it shows rather pronounced spots in the N.E.B.

No. (26) is considerably improved over the preceding. The N.P.R. is seen with a definite south edge. The N.Temp.B. fades towards increasing longitudes. The N.E.B. is marked with several condensations and is bordered on its south edge by a lighter band in the E.Z. In the S.Trop.Z. the Red Spot is rather well shown accompanied by a vestige of the Red Spot Hollow depression.

No. (32) shows marking somewhat advanced in longitude over those of Figure 4; as might be expected, the N.Temp.B. is absent.

No. (46) Separate white spots are resolved in the north part of the E.Z. and one indents the north edge of the N.E.B. "The S.Temp.B. was narrower than the S.Temp.Z., whereas it is usually the opposite."

No. (52) Both the S.Temp.Z. and S.S. Temp.Z. are seen.

No. (54) "Jupiter the wodnerful!" Compare this with the poverty of the first disks.

So far we have dealt with forms of detail but not with the subtler matter of colours. It is much more difficult to make as unambiguous a record of them and I shall here only venture the opinion that Jovian colours appeared to become richer and more distinguishable during the course of this 1937 apparition study.

Returning to detail forms, these vary considerably from planet to planet and it is worth while to inquire whether eye training on one has utility in application to another. If one began observing two or more planets at the same epoch it would be impossible to disentangle the effects of training for each itself and suspected transfers. It so happens that in 1937 I did begin observing Mars about the same time as Jupiter but did not attempt Mercury or Venus systematically until September. I think that in that and the following month I saw these latter objects about as well as at any subsequent time. My uncertain opinion is that particular eye training does have applicational value over a more general domain than its own. This domain, however,

must surely consist only of a specified family, such as the planets I mention, and not of a whole class of celestial objects.

We come to the question of permanence of retention of eye training, and the ease with which the vision once trained regains its powers if it suffers any regression from lack of employment. In any case I judge that my eye loses but little in several months of inactivity, as when a planet is too near the sun for observation, and regains that quickly. But the problem is really too complicated if one deals with observations already made with no design for solving it. For example, in 1938, '39, '40, and '41 I began observing Jupiter much earlier in the apparition than in 1937 so that the planet stood poor seeing in low altitudes just before sunrise. Then as soon as seeing became better in the apparition details were more plentiful.

Finally I mention that in the first year or two of regular observing I settled on the habit of using the left eye nearly exclusively at the telescope. It is of interest therefore to note that the right eye has shown little or no sympathy with the left and has remained relatively unskilled. The appearance of a planet to the right eye as compared with that to the left is less sharpness and greater brightness, the latter impression even at first glance with alternate eyes when they should have been equally sensitive to the light.

126 Albemarle Street, Rochester, New York.
January 2, 1944.

THE LUMINOUS PATHS OF METEORS

By R. A. McIntosh

THE path length of a meteor is dependent upon the angle of incidence of the meteor in the atmosphere. The phenomenon, apparent to the observer from the fact that a radiant at a low altitude generally provides long-pathed meteors while those meteors emanating from a radiant near the zenith are extremely short, has never been examined quantitatively.

In making this investigation I have used the real heights computed and published by the late W. F. Denning.[1] Since inclinations were not published in the original data, these were calculated by slide rule from the following formula:

$$\sin i = \frac{H_a - H_d}{P}$$

where H_a and H_d are the heights of appearance and disappearance of the individual meteors and P the path length.

The mean path lengths of all meteors were divided into groups with class intervals of 10 degrees of inclination. This arithmetic means of each group are given in Table I, and illustrated graphically in figure 1, where the means have been smoothed by the formula:

$$x_s = \tfrac{1}{4}\,(x_{s-1} + 2x + x_{s+1})$$

They reveal the dependence of path length upon angle of incidence, those meteors with the least inclination to the atmosphere having the longest paths. The correlation coefficient was found to be

$$r = -0.42 \pm 0.02.$$

TABLE I

	Inclination (degrees)								
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-90
Path (miles)	123	71	61	47	40	34	33	32	28
Path smoothed (miles).....	(123)	81	61	49	40	35	33	31	(28)
No. of meteors ...	105	133	142	132	82	76	64	28	47

The curve depicted in figure 1 is compared in figure 2 with the

[1] *M.N.R.A.S.*, vol. 57, p. 164; vol. 72, p. 423; vol. 76, 219; *Journ. B.A.A.*, vols. 27, 29 and 32.

theoretical curve of path length in relation to angle of incidence deduced by Opik.[2] It will be seen that the agreement in nature between the theoretical curves for iron and stone meteors and the

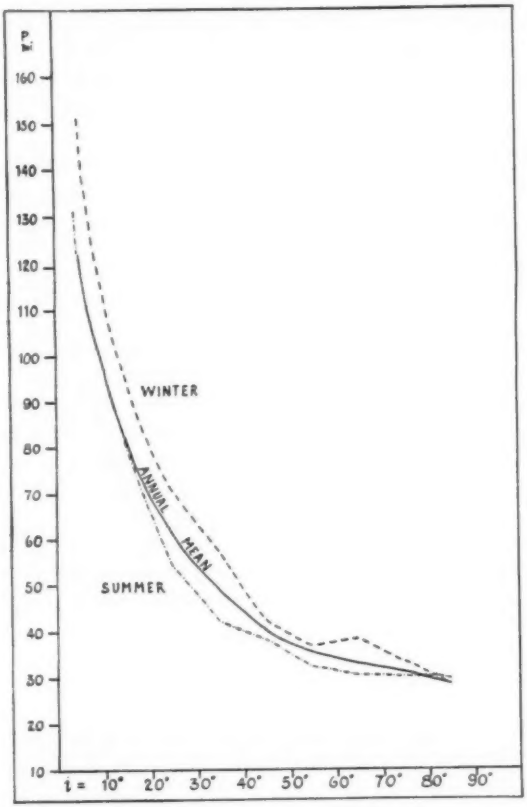


Fig. 1.—Path lengths of meteors in relation to inclination.

values actually observed is good, although the observed values lie below the theoretical. Since the latter are based on assumed tem-

[2] *Pubs. Ast. Obs. of Univ. of Tartu*, vol. 29, no. 5, p. 25, 1937.

peratures of volatilization, the disagreement indicates the possibility that meteors may become luminous at slightly lower temperatures than Opik estimated.

An arithmetical error occurs in Opik's value for $(q + h)/q$ for stone meteors (page 26 of his paper) where 2.95 should be 3.10.* The curve drawn in figure 2 is based on the corrected value. Since

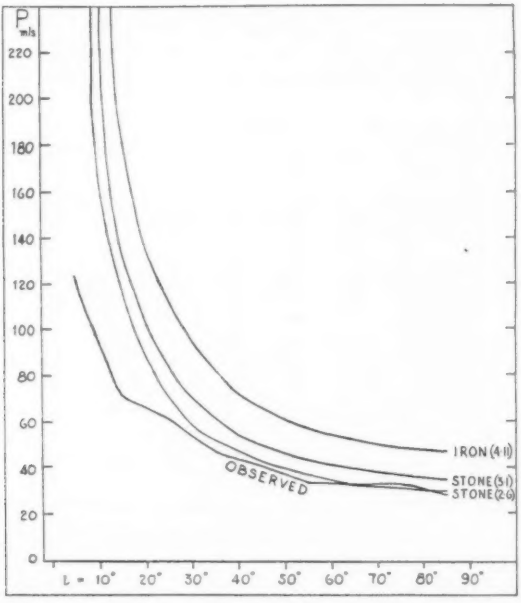


Fig. 2.—Theoretical and observed values of various inclinations compared.

the assumptions concerning the behaviour of stone meteors are uncertain, a further curve based on a value of $(q + h)/q$ of 2.60, which lies close to the observed values, is included for comparison.

Although the agreement between theory and observation is good at most inclinations, the discrepancy at the lowest inclinations (where the observed paths fall short of the lengths to be expected

*q is the heat up to vaporization, including fusion, and h is the latent heat of fusion.

from theory) may arise from the fact that the majority of meteors may be entirely consumed before the total possible path (over 500 miles) can be covered.

When the data are divided into quarterly periods, Table II, it is found that the path lengths are longer in winter than in summer. This is a result to be expected for, as shown in a previous paper,[3] although the mean height of appearance of meteors is higher in summer than in winter, the height at which they disappear rises considerably more, so that the width of the meteor zone (lying between these mean levels) contracts.

TABLE II

Inclination degrees	Jan.-Mar. no.	P mi	Apr.-June no.	P mi	July-Sept. no.	P mi	Oct.-Dec. no.	P mi	Whole Year no.	P mi
0– 9	23	151	33	90	32	141	17	148	105	123
10–19	21	78	30	67	51	71	31	73	133	71
20–29	24	73	25	62	56	53	37	65	142	61
30–39	18	58	28	46	48	39	38	53	132	47
40–49	11	38	11	35	32	37	28	47	82	40
50–59	14	34	16	33	27	32	19	39	76	35
60–69	13	40	12	32	27	29	12	33	64	33
70–79	4	37	7	31	12	31	5	31	28	32
80–90	10	30	9	22	18	29	10	29	47	28
Means..	138	71	171	56	303	54	197	60	809	56

Although there are insufficient shower meteors available for reliable deductions to be made, the few real paths available as given in Table III reveal that the trend for shower meteors resembles that for sporadic objects.

TABLE III

Inclination degrees	Leonids no.	*P* mi	*Ps* mi	*Sh-Sp* mi	Perseids no.	*P* mi	*Ps* mi	*Sh-Sp* mi
0– 9	4	154	(154)	−6	..	..	..	..
10–19	3	99	101	+28	4	46	(46)	−25
20–29	5	53	64	−1	24	52	50	−3
30–39	10	49	50	−3	70	49	48	+9
40–49	7	48	45	−2	22	44	43	+6
50–59	8	35	37	−2	6	37	(37)	+5
60–69	4	30	(30)	−3	..	..	..	..

[3] *M.N.R.A.S.*, vol. 100, p. 510, 1940.

In the above table the mean path lengths P, of Leonid and Perseid meteors of various inclinations are smoothed Ps, and compared with the values for sporadic meteors, *Sh-Sp* (Shower-Sporadic), occurring in the same quarter of the year. From the number available, (no.,) it can be seen that the table is statistically weak, but the residuals are small.

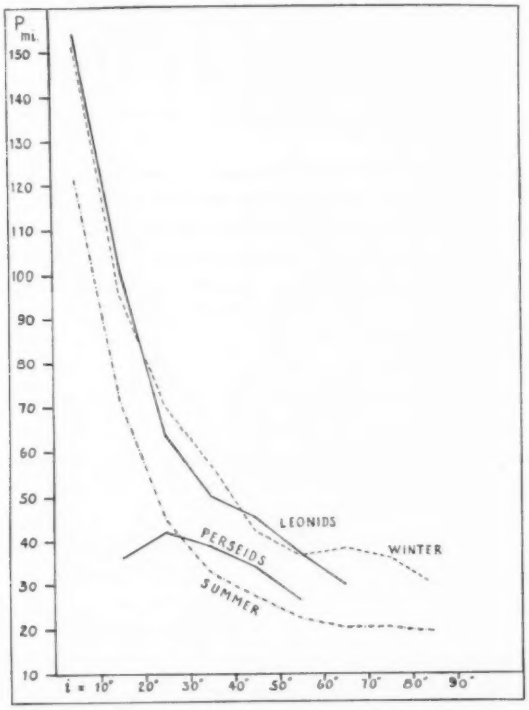


Fig. 3.—Sporadic and shower meteors' path lengths.

Another effect noted by observers is confirmed by statistical examination—that meteors from low-altitude radiants generally are brighter than those from radiants near the zenith. The data at my disposal reveal a fair correlation between magnitude and path length,

985 of Denning's meteors yielding a correlation coefficient of

$$r = +0.37 \pm 0.01.$$

This effect probably arises from increased distance and atmospheric absorption cutting out the fainter meteors.[4] The modes and median path lengths for various magnitudes are given in Table IV.

TABLE IV

Magn >	−12	−12	−11	−6	−5	−4	−3	−2	−1	0	1	2	3	4
Path-														
median (mi)...	65	93	68	70	61	52	50	51	55	45	40	32	26	25
mode (mi)	45	45	75	65	55	40	40	45	45	45	30	25	25	25
n.....	11	37	26	12	96	84	31	109	7	80	217	176	76	34

The heights of meteors in relation to their inclination indicate that, except in the case of the nearly-horizontal meteors (the mean of which naturally tends to occur toward the middle of the zone), the points of appearance and disappearance remain virtually constant throughout all inclinations, as will be seen by reference to Table V.

TABLE V

	Inclination (degrees)								
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-90
Ha (mi).....	61.6	65.3	70.1	67.4	70.3	69.2	71.1	70.2	68.1
Hd (mi).....	52.1	47.5	45.9	42.1	42.1	41.2	42.9	40.3	40.8
n.....	106	132	140	132	81	74	62	11	46

Examination of the apparent geocentric velocities of the meteors reveals that velocity has no relation to path inclination, the correlation coefficient being found to be

$$r = -0.03 \pm 0.02, \text{ from 868 meteors.}$$

Criticism of the methods of early British computers, and particularly those of W. F. Denning, has recently been expressed by J. G. Porter,[5] who states that the non-systematic errors allowed by the computer cannot be tolerated in a statistical investigation. Since I have made use of Denning's data in a number of recent papers (including the present one), some justification for my selec-

[4] Opik, *H.C.O. Bull.* No. 879.

[5] *M.N.R.A.S.*, vol. 103, p. 134, 1943.

tion seems called for. It was governed by two factors: In the first place, Denning's was the largest, most accurate and homogeneous contribution to the study of real heights available at the time and, in the second place, without it the various correlations and statistical inferences could not have been drawn. The alternatives before me were to search for correlations in data admittedly imperfect or to make no attempts to seek new facts about meteors.

Perhaps, however, Denning's data may not have been as unreliable as Porter's investigations lead him to believe. In support of this contention I would cite the following points:—

1. The distribution of errors appears to be normal (as Porter admits).

2. When the data are arbitrarily subdivided (as is done for instance in Table II of this paper) the agreement between the means of the several samples indicates that the means derived are reasonably reliable.

3. The discontinuity existing at the 37-mile level in the atmosphere first shown by Lindemann and Dobson[6] would be masked out if the errors inherent in the data were at all large.

4. The observed relation between the velocity and height of meteors[7] agrees closely with the theoretical expectation.

5. The mean observed velocities of shower meteors (which depend upon accurate path lengths, and therefore heights, as well as durations) agree closely with the theoretical velocities,[8] the mean difference between observed and theoretical velocities for 165 meteors amounting to only −0.3 miles a second.

6. The observed path lengths of meteors vary in close agreement with the curves to be expected from the theory of atmospheric friction (figure 2 of this paper).

7. The means of the differences in heights of 172 objects (shown in Porter's paper) between the original treatment by Denning, where "each path was liable to adjustment by the computer exercising an independent and non-methodical judgment," and the recomputation by Porter following rigid mathematical formulae amounted to only

[6] *Proc. Roy. Soc.*, A, vol. 111, p. 411, 1923.
[7] *Journ. R.A.S.C.*, vol. 37, p. 314, 1943
[8] *Ibid.*, Table I.

+2.1 miles at beginning and −0.5 miles at end of path, values no worse than the accuracy claimed for the data by Denning himself.[9]

These facts appear to me sufficient justification for my continued use of Denning's material.

Summary

The path lengths of meteors are shown to be dependent upon the inclination of their paths in the atmosphere, the length of path varying inversely with the altitude of the radiant above the horizon.

The heights of meteors are not affected by slope of path, while distance and atmospheric absorption probably account for the longer-pathed meteors being brighter.

A number of features revealed in Denning's data are cited in support of the claim that the data are suitable for statistical analysis.

Private Observatory, 30 Dickens Street,
Auckland W.2, New Zealand,
20 February, 1944.

[9] *M.N.R.A.S.*, vol. 73, p. 395, 1913.

THE NATURE OF THE GALAXIES*

By Francis P. Morgan

IN discussing the nature of the galaxies, let us first consider the Milky Way as a galaxy.

It is estimated that 99 per cent. of the stars which make up our galaxy are within a large cart-wheel-shaped structure, having a diameter of 100,000 light-years, a thickness of 10,000 light-years in the neighbourhood of the sun, the sun being located at a distance of 32,000 l.y. from the centre. The sun's period of revolution around the centre is about 225,000,000 years, from which the mass of the galaxy is computed as 170,000,000,000 solar masses.

We are really located within the "suburban" region of our galaxy, and there are two reasons why we believe this to be the case. First, because the star density in the sun's neighbourhood is the same as that in the outer regions of the spiral nebulae; second, because the twist in the rotation of our galaxy, as indicated by the radial velocities of stars in low galactic latitudes, indicates most of the mass to lie in the direction of the centre.

Our galaxy is surrounded by a globular framework of very loosely scattered stars. This is outlined by the distribution of the globular clusters, which are scattered around both sides of our galaxy out to about 50,000 l.y., and which extend well beyond the limits of the main body of our galaxy.

Also distributed through this same volume of space are cluster-type variables, stars resembling the Cepheid type, but with periods of less than a day and of negative absolute magnitude. Their distances are easily computed, and there are doubtless many non-variable stars among them although we have no way of determining their distances. Their orbits are probably very elliptic and inclined at all angles to the plane of the Milky Way.

The nearest of the external galaxies are the Magellanic Clouds. It is rather unfortunate that they belong to one of the rare types of galaxies, for if they were spiral, as the majority of galaxies are, their nearness would yield important information on the nature of galaxies in general.

*An Address given to the Montreal Centre, Royal Astronomical Society of Canada, on Thursday, 24th February, 1944.

The Large Cloud is 75,000 l.y. distant and 12,000 l.y. in diameter. It is irregular in shape and looser in structure, but its stellar content is much the same as the Milky Way except that its brightest stars are much brighter than any that are known for our galaxy. The brightest star of all, S Doradus, is about 500,000 times as bright as the sun. It is an eclipsing binary with a 40-year period, and its light also varies in an irregular period. Many bright and extensive diffuse nebulae are present with clusters of supergiant stars within them. The Cloud contains thirty globular clusters and many Cepheid variables. About 2 per cent. of all the supergiants are Cepheid variables, but the percentage varies from 4 per cent. in the dense central region to 0.5 per cent. in the outer regions. They have not, as yet, been extensively studied as to the distribution of their periods.

The Small Magellanic Cloud, at a distance of 85,000 l.y., is only half the size, namely, 6,000 l.y. in diameter, but it is very similar in all other respects. The Cepheid variables have been more extensively studied than those of the Large Cloud, and it is found that in the central region the most frequent period is from four to five days, although all periods from two to forty days are present. This is true of the classical Cepheids in our own galaxy. In the outer regions, however, the two-day period is most frequent, and in our own galaxy these stars are the most scarce.

Since the luminosity of the Cepheids increases with period, it would appear that in the Magellanic type of galaxy, the brightest and heaviest stars are found where the stars are most crowded.

The next in order of distance is M33 in Triangulum, at a distance of 700,000 l.y. Its diameter is 12,500 l.y., a typical open spiral. It is believed to resemble our galaxy in all respects except for its size and mass. It contains the same types of stars and is very similar in rotational properties.

Mayall and Aller at Lick Observatory have studied the radial velocities of many bright-line diffuse nebulae distributed throughout M33, and find a rotation period of 60,000,000 years for the central region out to a radius of 3,500 l.y. This part rotates as a solid body. Beyond 3,500 l.y. a lag occurs, the rotation period increasing to 150,000,000 to 200,000,000 years out to a radius of 6,000 l.y. From the above data the mass of the system is computed as 1,000,000,000

solar masses, or less than 1 per cent. of that of our own galaxy. The nuclear region has never been resolved, but the spectrum leaves no doubt about it being composed of stars although no supergiants are present in this region. The stellar content of the nucleus and that of all other spiral nebulae is probably the same as for globular clusters, except for being much larger and more compact.

M31 in Andromeda is at nearly the same distance as M33, and more closely resembles our galaxy as to size than any other known galaxy, but there are important differences in other respects. It is an intermediate-type spiral, type SB, with a relatively larger nucleus and more closely coiled spiral arms. It is 40,000 l.y. in diameter, and the nuclear region rotates once in 16 million years. Babcock at Lick Observatory has studied the rotation of M31 and computes the mass as roughly 100,000 million solar masses, more than half that of our galaxy. Its brightest stars are about the same as those of M33 and our galaxy, but most of the light is contributed by the unresolved nebulosity, indicating a lower percentage of giants than are present in open spirals.

There are two small companion galaxies to M31. One is M32, a small elliptic nebula of 1,800 l.y. diameter. It has never been resolved into stars and the spectrum is similar to that of spiral nebulae, indicating that it is composed of the same types of stars. These characteristics are similar to those of elliptic nebulae in general, but M32 is much smaller than average.

The other companion, NGC 205, is a peculiar type, being shaped similar to an elliptic nebula, but, unlike the latter, it contains stars bright enough to be resolved, and dark patches of dust lie within it. The spectrum also differs from that of ellipticals.

The seven galaxies mentioned above are part of a local group of eleven. The remaining four are two small galaxies of the Magellanic type, very similar but smaller than the Magellanic Clouds, and two Sculptor galaxies.

The latter are an entirely new type of galaxy, discovered only in recent years, and so far the only two to have been discovered. The first discovered was the one in Sculptor, hence the name. It resembles a giant globular cluster, having a diameter of 5,500 l.y., but its stars are more loosely scattered. The dimensions are the average of that of normal elliptic nebulae and its shape is also similar

to the more spherical form of the latter, but it contains only 10 per cent. as many stars, and, unlike ellipticals, it is apparently free of absorbing material.

The other one is in Fornax and is larger, having a diameter of 9,500 l.y. There are also three small globular clusters within it. The Sculptor and Fornax clusters are 250,000 and 500,000 l.y. away respectively. It is because they are so faint and can be recorded only on long exposure plates that they were not discovered sooner.

There are various methods of determining distances. The nearer galaxies can be measured for distance and dimensions by the study of the Cepheid variables which they contain, by applying the period-luminosity relation. For those more distant which can be resolved, the fifth brightest star serves as a fairly reliable standard of absolute magnitude for distance determinations. For those too distant to be resolved, and for ellipticals which cannot be resolved at any distance, we must rely on statistical methods.

Fortunately there is a strong tendency for clustering, and if a cluster contains a sufficiently large number of galaxies, the average absolute magnitude of its members is likely to be the same. Fortunately also, there is one large cluster which is near enough to be resolved, namely, the Virgo Cluster of galaxies. Its distance, as determined by the distances of its resolvable members, is roughly seven million light years. The average luminosity of its members is computed as $M = -14.2$. This value is probably close to the average for all cluster members, where the cluster contains enought members to make a good average.

Galaxies are classified into two main types—spiral and elliptic. The former are subdivided into three types, according to the relative sizes of the nuclear regions and to how closely coiled or open the arms are. They are SA, SB and SC for closed, intermediate and open spirals respectively. M33 and probably also our galaxy are SC types. M31 is of the type SB. Elliptic nebulae, of which M32 is an example, are classified as E0 for the most spherical objects to E7 for the most elliptical types.

About 75 per cent. of all galaxies are spirals and 20 per cent. are ellipticals. The remaining 5 per cent. are the rarer types, like the Magellanics and the peculiar types. By a strange coincidence, seven out of the eleven known members of the local group are of the

rare or peculiar types, although Sculptor types may be more common than they appear to be, being so difficult to detect.

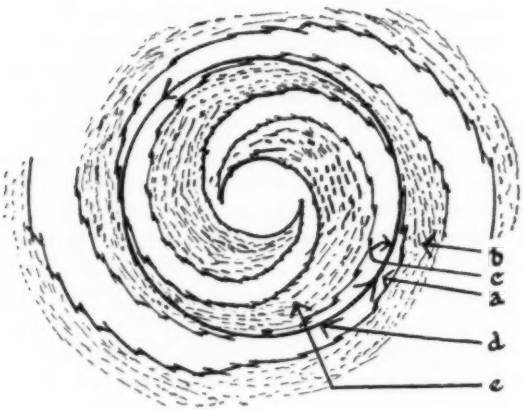
The dimensions of the objects referred to above are those of the main body, that is, the part that can be photographed on plates at a moderate length of exposure. Longer exposures reveal fainter extensions of the image beyond the main body. A new instrument has come to the use of the astronomer, the microdensitometer, which employs the use of the photo-electric cell in recording very faint light impressions recorded on a photographic plate. This instrument reveals a faint haze of light surrounding all types of galaxies and its outline is nearly spherical. In all probability this haze consists of a system of loosely scattered stars moving in elliptical orbits, like that surrounding our own galaxy. In the nearer objects, globular clusters are found distributed throughout this haze, as many as 140 being found in M31 and 30 in the Large Magellanic Cloud.

Of special significance is the fact that the extent of this globular envelope varies with the brightness of a galaxy but does not vary with type. Thus, the total dimensions of an open spiral are no greater than that of an elliptical, as was once believed, the intrinsic brightness being equal. This suggests that the spiral arms are formed by a condensing of stars within the system, rather than of stars ejected from the nucleus, as was once believed.

One of the strange results of modern research on the rotations of spirals is that they rotate in such a manner as to indicate that at the outer portions of the arms there is much weight and very little light, the M/L ratio being of the order of 100 to 1 or greater (in terms of the sun.) The generally accepted belief is that this is due to an increase in the proportion of dwarf stars from the centre outward. It is a personal opinion that if this were the explanation the spectrum would tell the story. The spectrum of the nucleus would be of an earlier type and the light bluer than that of the outer regions. In fact the opposite is true. The spectrum of spiral nucleae are of type F or G, while that of star clouds in the outer regions which are bright enough to show a spectrum are of type A or B. Also there is an increase rather than a decrease in the colour index as the centre is approached.

In my opinion the rotational properties are best explained by an increase in the density of dust or gas, or both, from the centre out-

wards. In a previous article I explained why the distribution of dust, while showing a strong preference to the common plane, would attain highest density in those regions of the plane where stars were most scarce. (See "Effects of Radiation Pressure on Cosmic Dust," this JOURNAL, Dec. 1942 and Jan. 1943.) These regions are the open spaces between the arms. If we also suppose that the dust and gas increase in density along these zones from the centre outward, we also have an explanation for the uniform rotation period and this, in turn, explains the permanence of the spiral structure. If, as would have to be the case, there is more matter between the arms in dust and gas than there is present within them as stars, then the arrangement of the stars into spiral pattern is explained in the following manner.



Referring to the accompanying drawing, the unshaded areas are the spiral arms, the shaded areas and dense dust zones between the arms. The circle is that of a stellar orbit. Since this portion rotates nearly as a wheel, the orbital motion of the stars and the rotation of the arms as a whole are almost one and the same thing, the direction of rotation being such that the arms trail, as indicated.

Suppose that a star at *a* moves too far ahead until it reaches *c*. It is now close to the dense dust zone *b*. Owing to the curvature of

this zone the star is drawn forward or accelerated, its distance from the centre is increased, and so it lags behind to a point just a little outside of its original position at *a*. If it lags too far behind, at *d* its motion is slowed down by the attraction of the zone *e*. This brings it closer to the centre and it moves forward to its original position at *a*. Note that the circle intersects the arms at points 90° from the points where it crosses the dust zones.

The theory may be objected to on the grounds that there is much light between the arms, but these regions need not necessarily be devoid of stars, but point *a* on the drawing is the most stable for the reasons described above. Also, since the dust is mostly confined to a narrow equatorial plane, it could have a density of 100 times that in the sun's neighbourhood and still be transparent to stars embedded within it if the spiral is viewed face on. Then again, the material may be mostly gas, which has high transparency.

There seems to be much doubt as to whether the sun is located within a spiral arm or in the more vacant regions between the arms. It is a personal opinion that neither assumption is correct, that all of the spiral structure in our galaxy is much nearer the centre than the sun, and there are four reasons why I believe this to be the case.

First, in M33, which is similar in many respects to our galaxy, the region where the star density would be the same as in the sun's neighbourhood seems to lie beyond the outer ends of the arms. (Reproduction of a Harvard Observatory photograph in "The Milky Way" by Bok.)

Second, the M/L ratio of the outer ends of the arms as computed from the rotations is as high as 100 to 1 or greater, as compared to 2.6 to 1 as estimated for the neighbourhood of the sun.

Third, in other spirals most of the brightest stars are found at the outer ends of the arms. In our galaxy the Cepheids and blue supergiants which represent the brightest stars are most numerous towards the galactic centre. If the arms extended beyond the region of the sun, they would be most numerous toward the anti-centre.

Fourthly, the twist in the rotation of the galaxy at our distance from the centre is so great that if the arms originally did extend to the sun, they would by now have disintegrated into local star clouds and dark nebulae uniformly distributed around the centre. We

have only to remember that the sun has made nine revolutions around the centre during the 2,000,000,000 years set by geologists for the age of the earth.

It is not my purpose to try to explain either the origin or development of the galaxies, but only to interpret some of the observational data, and to explain certain dynamical problems of spiral galaxies as they are at the present time.

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REVIEW OF PUBLICATIONS

Meteorology, Theoretical and Applied, by E. Wendell Hewson and Richmond W. Longley. 457 pages, 6 in. x 8½ in. John Wiley & Sons, New York. Price, $4.75.

Recent years, the interval from 1914 to the present, has seen marked advances in the theory of meteorology. These advances have found expression in an increasing number of texts embodying the new ideas. Fifty years ago chief emphasis was placed on the areas of high and low barometric pressure as controlling the weather. Since the advent of the frontal theory of Bjerknes these have been regarded as attending phenomena to a more fundamental condition which depends on the movements of air masses and their lines of junction. Fifty years ago, also, ideas were based mainly on the phenomena as displayed at the surface of the earth. With the greatly increased facilities for exploring the conditions at various elevations our knowledge of meteorological phenomena has become more precise and meteorological conditions are recognized, as they must be, as three dimensional. The authors have given a very able presentation of the new viewpoint.

The text is divided into two parts. The first part develops the thermodynamics and hydrodynamics of the atmosphere. A fairly good knowledge of the calculus and a good knowledge of elementary physics is necessary to appreciate this part. Two rather brief chapters, the first on statistical analysis and the second on harmonic analysis are included in this part.

The second part deals with the application of the theory to the methods of forecasting. It starts out with a chapter on meteorological instruments and observations of the meteorological elements. This is followed by a brief chapter on the general circulation. The parts played by temperature and moisture are treated in the next chapter and then the conditions for stability and instability are discussed. In the fifth chapter the various air masses are recognized and their properties described. The development of the cyclones and anticyclones along the frontal surfaces is treated in the next chapter. Then follow chapters devoted to the winds, precipitation, fog, clouds,

icing, respectively. A separate chapter is devoted to the electrical properties of the atmosphere and the mechanism of the thundershower. The last chapter but one deals with map analysis and forecasting procedure, the plotting of the weather map, the identification of air masses and the location and movements of the front and the accompanying phenomena. A detailed example is worked through. The book closes with a chapter on the part meteorology plays in various human activities.

The binding, paper, and printing of the book are excellent.

R.K.Y.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Book Publishing and the War

An article in the April *Bulletin* of the American Association for the Advancement of Science surveys the great contributions which American (and English) University Presses are making in the publishing of books directly and indirectly important in the war effort. The article further calls attention to an editorial from the *New York Times* discussing the relatively small amount of man-power and material being used annually by the whole book publishing industry of the United States.

> All book publishing in the United States employs fewer than 5000 men and women and book manufacturing employs only a little more than three times as many. The paper needed for the 275,000,000 volumes turned out last year was only six-tenths of one per cent. of the paper processed last year, and the cloth used for binding them was less than one-tenth of one per cent. of the country's production of "gray goods." How inadequate is our comprehension of this new world which our technology has created!

Considering that a large part of book publishing is at present devoted to strictly essential books—textbooks, service manuals and technical works—it is evident that any further restrictions on the publishing industry could effect only a microscopic percentage saving in paper, cloth and man-power.

F.S.H.

American Astronomical Society Meeting

The seventy-second meeting of the American Astronomical Society is being held on June 28-29, 1944, in Philadelphia, Penna. The business session and the sessions for scientific papers will be held at the Hall of the American Philosophical Society. The programme will also include a special demonstration of the Fels Planetarium of the Franklin Institute, and visits to the nearby Flower, Cook, Sproul and Haverford Observatories.

F.S.H.

PROGRESS OF CALENDAR REFORM

Of the pleasing pilgrimage to Canada of Miss Elisabeth Achelis, president of the World Calendar Association, and Mr. Emerson Brewer, editor of the *Journal of Calendar Reform*, in January last, there is a good account in the issue of that magazine for the first quarter of 1944.

Miss Achelis had an engagement to lecture before the Ottawa and Montreal Centres of our Society on January 19, 20; and she and Mr. Brewer stopped over for a short visit in Toronto. They were the guests there of Mr. J. R. Gilley, B.A.Sc., Acting Warden, and Mr. W. R. Cowan, B.A.Sc., Acting Controller, of Hart House, the great Students' Union of the University of Toronto. Mr. Gilley in 1935 contributed to this JOURNAL an excellent article on Calendar Reform.

There was a luncheon attended by a group of representative people in Alexandra Palace Hotel. After the luncheon Miss Achelis spoke briefly on The World Calendar and then an informal discussion followed. Among those present was Dr. R. H. Coats, formerly Dominion Statistician but now Visiting Professor of Economics in the University, who very neatly gave his reason for favouring the proposed calendar by saying that it is the happy mean between the present unsatisfactory Gregorian calendar and other more radical and "revolutionary" proposals. This is undoubtedly the view of many who have given consideration to the matter. Later in the afternoon a tea was held in the Warden's Study at Hart House, at which there were present President and Mrs. Cody and a number of ladies occupying responsible public positions in Toronto.

In Ottawa a luncheon was given at the Country Club for Miss Achelis and Mr. Brewer by A. J. Hills, Chairman of the National Joint Conference Board of the Construction Industry, and H. S. Southam, publisher of the *Ottawa Citizen*, which, by the way, is always generous and helpful to our Society. The visitors also met a number of distinguished men at the Parliament Buildings and at the luncheon. For the lecture in the evening Dr. T. L. Tanton, president of the Ottawa Centre, was chairman and introduced the speaker, who, in the course of her address, urged that now is the time to change to the new calendar. She remarked that no war is won by delaying improvements and no success is achieved by clinging unwisely to outmoded

patterns and systems. The new calendar is not designed for astronomers but chiefly to assist civilians in their everyday life.

At Montreal the visitors were met and entertained at dinner by Mr. Dan P. Gillmor, K.C., president of the Montreal Centre, and there were present Miss Isabel Williamson, Henry F. Hall, F. DeKinder, G. Harper Hall and DeLisle Garneau, members of the Council of the Centre. The lecture was given in the McGill University Amphitheatre and the audience indicated that along with post-war planning we should support the adoption of The World Calendar.

C.A.C.

Miss Achelis' Book on the Calendar

In her new book entitled *The Calendar for Everybody* (141 pages, Putnams, N.Y., 1943, $1.50) Miss Elisabeth Achelis, in a sane, thoughtful and reverent manner, gives reasons for adopting The World Calendar. The idea of a calendar with four equal quarters is not original with Miss Achelis, but she adopted it and has urged it in a wise and convincing way. The following is from a review of the book in the *Ottawa Citizen*:

> Why should we adopt a new calendar? Because it is time we modernized our civil calendar and brought it into tune with the times. The present one is full of drawbacks and eccentricities. The World Calendar will give us the most perfect time measurement yet devised.
>
> In civil life, the new perpetual calendar would bring many improvements. To take but one phase of civil activity—government—The World Calendar would lighten the task substantially. The fiscal year would begin always on the same day and date. It would materially simplify comparisons of statistics. The records on customs receipts, income taxes, internal revenue collections and interest paid or received, will be more easily computed. And for the various government departments which require accurate quarterly financial statements, the advantages of The World Calendar, with its equalized quarterly divisions, are apparent. The same considerations apply to every other branch of modern activity.
>
> Miss Achelis feels very deeply the merits of the new calendar. She says it will "contribute towards making a better world, making life more beautiful, and making my fellowmen happier." After reading her book one begins to catch that mood of inspiration one's-self.

C.A.C.

Odd Names and Pronunciations

One comes across some strange surnames and peculiarly spelled Christian or "given" names, and wonders how they originate. Long years ago the present writer read that in a certain place in the "Old Country" it was customary at a christening for the father to open the Bible and choose the first proper name which met his eye. On one occasion the name Ramoth-gilead was the first seen and the child bore that name through life. To the writer's personal knowledge the name given by a father to a son was "Mr. J. G." The child grew to manhood, when "Mr." fitted him naturally.

All this leads to a name of more scientific flavour which was recently met with in the sunny south. An elderly gentleman from about latitude 40½ north informed the writer that his name was Space. Does anyone know of a surname Time?

This seems a good opportunity to refer to a pronunciation which to the writer seems peculiar. There is a class of variable stars called Cepheids, named after a typical example in the constellation Cepheus. Now in the Greek language the second letter in this word is *eta* which in English is pronounced long *e*, and the English language pronunciation of Cepheus is *see-fuce*. From this the pronunciation of Cepheids would naturally be *see-fe-ids*, and yet one often hears *seffy-ids*.

C.A.C.

MEETINGS OF THE SOCIETY

AT TORONTO

October 19, 1943—The Toronto Centre participated with the Royal Meteorological Society (Canadian Branch), the Royal Canadian Institute and the University of Toronto in two sessions to commemorate the Tercentenary of the Invention of the Barometer by Evangelista Torricelli in 1643.

The afternoon session, under the chairmanship of Dr. C. A. Chant, was held in West Hall of University College.

Delegates from other societies were received and spoke briefly, as follows: Dr. Andrew Thomson of the Meteorological Service of Canada, representing the Royal Society of Canada; Dr. C. G. Andrus, U.S. Weather Bureau, Cleveland, Ohio, representing the American Meteorological Society, and Dr. Louis C. Karpinski of the University of Michigan, President of the History of Science Society.

Dr. Karpinski then addressed the meeting on "The Telescope, Microscope and Barometer as a Point of Departure for the Natural Sciences". This was followed by an address by Dean G. S. Brett, School of Graduate Studies, University of Toronto, on "The Effects of the Discovery of the Barometer on Contemporary Thought".

The evening session, held in the McLennan Physics Laboratory, took the place of the Society's regular meeting. Dr. John Patterson of the Meteorological Service of Canada was chairman. He re-enacted the experiment of 1643 by which Torricelli demonstrated that the weight of the atmosphere could support a column of mercury in a closed tube.

Mr. W. E. Knowles Middleton of the Meteorological Service of Canada then addressed the meeting on "The Subsequent History of the Barometer". Dr. John Satterly, Department of Physics, University of Toronto, presented the final paper on "The Applications of the Barometer in Physics and Chemistry". Professor Chester Martin also spoke briefly.

These four papers have been printed in this JOURNAL, December 1943—February 1944.

Following adjournment of the public meeting, a brief business meeting of members of the Royal Astronomical Society of Canada was held with Miss R. J. Northcott in the chair. Minutes of the previous regular meeting, held on October 12, 1943, were taken as read.

Sixteen applicants, nominated at the previous meeting, were duly elected to membership in the Society, viz:

Mr. Joseph Richards, 17 Keystone Avenue, Toronto.
Mrs. George Carruthers, 236 Indian Road, Toronto.

Mr. J. G. Muir, 191 Ellis Avenue, Toronto.
Mr. Albert J. Woodward, 1081 Dufferin Street, Toronto.
Miss Winnifred Brabant, 27 Delaware Avenue, Toronto.
Mr. Robert Olave McCauley, 73 Cambridge Avenue, Toronto.
Mr. Morris Handelman, 1 Afton Avenue, Toronto.
Mr. James C. Williamson, 20 Costain Avenue, Toronto.
Mr. Gerald J. Pawlowski, 261 Borden Street, Toronto.
Mr. W. G. Noble, 3 Conrad Avenue, Toronto.
Mr. William G. Mayberry, 10 Earl Haig Avenue, Toronto.
Mr. Richard H. Garrett, 14 Earl Haig Avenue, Toronto.
Miss Louise Boothe, 174 Kingswood Road, Toronto.
Mr. Leo F. Willey, 31 Bartonville Avenue, Mount Dennis, Ont.
Mr. William J. McCallion, 18 Louvain Avenue, Mount Dennis, Ont.
Mr. Harold England, Barber Avenue, Thistletown, Ont.
The meeting was then adjourned.

FREDERIC L. TROYER, *Recorder.*

A QUEBEC

Le 26 janvier 1944—Cette séance régulière de janvier a été tenue dans l'amphithéâtre Lavoisier, à l'Université Laval, sous la présidence de M. Jean-Charles Magnan.

Il y eut d'abord admission des nouveaux membres suivants: MM. Jean Bélanger, l'abbé F.-X. Côté, J.-G. Dostie, Raymond Fortin, Geo.-E. Gagné, le Rév. Père Henri Gauthier, Paul-Emile Houde, Richard Jobin, Paul-Emile Levesque, Benoit Marcotte (Section des Jeunes), Charles-Henri Potvin, Robert Proulx et Robert L. Smyth.

M. le Président a ensuite annoncé la réception de deux dons en faveur de notre bibliothèque: 100 numéros du *Journal* de la R.A.S.C. couvrant la période de 1930 à 1940, l'une des plus intéressantes de la vie astronomique au Canada, offerts par M. Arthur Amos, ancien Président honoraire du Centre de Québec; et une série complète des bulletins de la Société Astronomique de France depuis 1924 jusqu'à 1938, de la part du Centre de Victoria. En proposant des remerciements aux généreux donateurs, M. Magnan a souligné que la collection des bulletins de la S.A.F. était pour nous un trésor d'une valeur inestimable, à l'heure actuelle, et qu'elle contribuerait à rendre plus solides encore les liens d'amitié qui nous unissent au Centre de Victoria, depuis notre entrée dans la Société royale d'astronomie du Canada.

La causerie principale, donnée par M. Lucien Pouliot, vice-président et trésorier, avait pour titre: "Les astéroïdes, 'les pierres tombées du ciel' et les cratères météoriques". M. Pouliot a parlé en particulier du célèbre *Meteor Crater* de l'Arizona et de la météorite tombée en Sibérie en 1908. D'après lui, le petit étang qui se trouve situé à un demi-mille de Lévis, sur les hauteurs,

et que les collégiens ont baptisé du nom pittoresque de *Mer à Popon*, pourrait bien avoir été creusé par la chute d'une météorite d'assez grandes dimensions. "Il serait intéressant, a-t-il dit, de faire des recherches à ce sujet et d'obtenir des preuves scientifiques de son origines".

Le programme de la soirée comportait aussi une description du ciel de février par M. Charles-Aimé Giroux.

PAUL-H. NADEAU, *secrétaire.*

AT MONTREAL

December 16, 1943—On the occasion of its Twenty-Fifth Annual Meeting, held on December 16th, 1943, Mrs. E. R. Adair addressed the Montreal Centre, choosing as her subject "Winds and the Weather."

Wind is simply air in motion and in considering this subject we must keep in mind four fundamental truths: (1) warm air expands and rises, (2) cooled air contracts and falls, (3) air loses heat by expansion and gains heat by compression and (4), just as water always seeks a lower level, so air moves from high pressure areas to low pressure areas.

With the aid of diagrams and slides the speaker explained the calm, low pressure area at the Equator where the air warms and rises; the calm, high pressure areas at the Tropics of Cancer and Capricorn where the air, cooling, descends; and the Northeast and Southeast trade-winds caused by the air rushing in to take the place of the warm rising air at the Equator. If the earth were stationery the trade-winds would be due north and south, but because of the earth's rotation they are given an eastern twist. (The name "trade-wind," incidentally, has nothing to do with commerce, being derived from a Middle English word meaning "to tread a path.") North of the Tropic of Cancer are the westerly variables, so called because their course is frequently changed by the mountains over which they pass. The prevailing winds south of the Tropic of Capricorn encounter little land and sweep over those latitudes in a manner that has earned the name "roaring forties." At the poles are the "polar calms" which one would expect to be high pressure areas but, for some reason as yet unexplained, are low pressure areas.

The unequal distribution of land and water causes many variations in the winds for land heats and cools more quickly than water. During the day as the land heats the wind blows from the water. Then the land cools and for the brief period when the land and water are the same temperature there is a calm before the wind reverses and blows from the land. The monsoons, which have such an effect upon the climate of Asia, are, as Mrs. Adair explained, "land and sea breezes" on a large scale.

The fact that the earth's axis is at an angle of 23½ degrees to the plane of the ecliptic also affects the weather for as the earth makes its yearly revolution around the sun the "heat equator" moves 5 to 10 degrees north or

south over the sea and shoots considerably farther north and south on land. This causes a seasonal shift in the wind belts which gives to certain areas a "Mediterranean climate" with the wet, cool winters and dry, hot summers particularly inducive to vegetation.

The second part of her lecture Mrs. Adair devoted to the tides. As we know, the tides are caused by the attraction of the sun and the moon, the latter, being nearer, exerting the greater influence. But the question is often asked, "Why are there tides on both sides of the earth at once?" The answer lies in the fact that although water is more yielding, the gravitational pull is felt by the land also. On the side of the earth nearest the moon the water is piled up over the land. On the side of the earth diametrically opposite, the moon exerts an influence on both land and water, but the land being nearer feels it more strongly and thus the tide is caused by the land "being pulled away from under" the water. The spring tides ("spring" meaning "welling up") occur twice a month—at new moon when the moon and sun are pulling together, and at full moon when the moon is opposite the sun. The neap tides occur at the first and last quarters when the sun and moon are at right angles pulling against each other.

Using a slide showing the co-tidal lines, Mrs. Adair explained why some parts of the coast have exceptionally high tides while others have none at all. The tidal wave sweeps up the Mid-Atlantic at 700 miles per hour but around the British Isles its speed reduces to 40 miles. Because of the position of the Isle of Wight the harbour at Southampton enjoys four high tides daily. The Mediterranean, on the other hand, has a tide of only one foot, while the absence of tides along the north-west coast of northern Europe accounts for the formation of deltas at many of its rivers. All these facts have a definite influence on the navigation, trade and industries of the countries concerned.

January 20, 1944—Miss Elizabeth Achelis, President of the World Calendar Association, Inc., was the speaker of the evening.

The need has long been felt for a calendar which offers an order and stability that the erratic Gregorian calendar lacks, said Miss Achelis in introducing her subject, and now, when ideas and ideals are directed towards greater world co-operation, seems the time to adopt the new World Calendar.

In the proposed World Calendar the twelve months are arranged into equal quarters of 91 days, the months following a rhythmic pattern of 31, 30 30 days. Each quarter begins on a Sunday and ends on a Saturday. Thus the year always begins on Sunday, January 1, and closes on Saturday, December 30. To complete the year the necessary 365 day, an extra Saturday called the Year-End Day and dated December W, follows after December 30. This is the new World Holiday and may become, as the name implies, the all-inclusive World Holiday of universal brotherhood and unity without interference with existing feast days. The Leap-Year Day, the old February 29, becomes another World Holiday, placed as another Saturday, June W.

One of the outstanding advantages of the World Calendar is the fact that each month has 26 business days whereas in the present calendar the months vary from 24 to 27 business days. Miss Achelis spoke of the difficulties encountered under the present system by the manufacturer and the industrialist, wage-earner and employer alike, and those in the educational field.

The opportune moment to put any new calendar into operation is at that particular time when the day, date, month and year coincide in both the old and the new calendars. By this simple method the year of confusion (when the Julian year became operative), and the dropping of 10 days (when the Gregorian calendar became effective), will be avoided. Miss Achelis pointed out that two such dates occur in the year 1945, two in the year 1946, and then the next possibility would be Sunday, January 1, 1950. The proposed calendar has already received considerable support, fourteen nations and many national and international organizations have endorsed it.

February 24, 1944.—Mr. Francis P. Morgan addressed the Montreal Centre on "The Nature of the Galaxies." First he described the structure of the Milky Way, and then spoke of each galaxy in the local group to which our galaxy belongs. This group, formerly thought to be composed of nine galaxies, is now known to include at least eleven. The two recently discovered additions are an entirely new type—the Sculptor type, so called because the first was discovered in Sculptor. They resemble giant globular clusters but with more widely scattered stars, and contain very little inter-stellar material.

The methods of determining the distances of the galaxies were described; and after speaking on the general classifications of galaxies and the problems of rotational properties and spiral structure, Mr. Morgan gave his reasons for believing that our sun is located beyond the spiral arms of our galaxy.

In conclusion, Mr. Morgan spoke of the distribution of galaxies throughout space, referring to the "18th magnitude survey" being conducted by Shapley at Harvard and the recent work of Hubble at Mount Wilson. Mr. Morgan used a number of slides and diagrams to illustrate his lecture. (The paper in full appears in the present issue of the JOURNAL—*Editor.*)

March 30, 1944.—Dr. W. Rowles, Chairman of the Department of Physics, Macdonald College, McGill University, spoke on "Light—Our Best Messenger," dealing with spectroscopy as applied to astronomical research.

As early as the sixth century B.C. theories were advanced to explain the power of vision. According to some, the eye acted somewhat in the manner of a hand reaching out tentacles to feel the object or to peel off the surface and gather it into the eye. This latter theory is supported in Lucretius' poem "De Rerum Natura," from which Dr. Rowles read several passages. It was not until Newton's famous experiments that the true nature of light began to be realized. Now it is most simply, though not entirely correctly, described as a wave motion travelling through space at tremendous speed. Dr. Rowles referred to Galileo's painstaking but unsuccessful experiments to prove that light is not instantaneously transmit-

ted, because the distances used in the experiments were too small to detect the great speed of 186,000 miles per second.

After explaining that various kinds of light are simply differences in wave-length that can be accurately measured, Dr. Rowles made an interesting test on his audience. Holding up a bright green disk he asked them to stare at it for several moments and then transfer their gaze to a blank white surface. The mauve-coloured disk which then appeared before their eyes was due to retinal fatigue, concentration on the green having used but one of three sets of nerves in the eye.

In everyday life one can, if need be, get along without sight, using instead the sense of touch. For objects too small to be felt, e.g., blood cells, the eye is needed. For still smaller objects light does not convey the message in the usual manner because the object is smaller than the wave-length, but then the spectrum can be used. Dr. Rowles explained the principle of the spectroscope and showed coloured slides of the spectra of various elements, including titanium, neon, zeon and radium. This led to discussion of why atoms give out these colours and what an atom is like. Sir Ernest Rutherford proposed the nuclear atom, composed of a nucleus and revolving electrons. Hydrogen, the simplest of all atoms, consists of one proton and one revolving electron. On the basis of the Rutherford atom, Niels Bohr developed his theory that an electron has several orbits and can, under certain conditions, jump from one to another, emitting light when moving to a closer orbit and absorbing light when jumping to an outer orbit. His mathematical formula deals only with hydrogen, however, and the formulae for more complicated atoms have not been calculated.

With the use of slides the speaker showed the characteristic shift in the lines of the spectrum caused by the rapid approach or recession of the light-source, known as the Doppler effect; the distortion of the lines by the electric field, known as the Stark effect; and the double lines caused by the magnetic field, known as the Zeeman effect. By thus being able to interpret the lines of the spectrum the astronomer can use the spectroscope to determine the radial velocity of stars, their distances and diameters and their composition.

Although admittedly not an astronomer, Dr. Rowles expressed great interest in the discovery within the last two years of two new solar systems. Careful measurements of the double stars, 61 Cygni and 70 Ophiuchi, over a period of thirty years had revealed that in addition to proper motion, there was something disturbing, something too small to be seen. In each case the size of the "disturbance" was determined as small enough to be classed as a planet.

Time did not permit the speaker to go more fully into recent developments in spectroscopy, and as the audience was obviously eager to hear more, the chairman extended a cordial invitation to Dr. Rowles to address the Centre again at some future date.

April 14, 1944.—Dr. J. W. Bridges, Professor of Psychology and Anthropology at Sir George Williams College, addressed the Montreal Centre on "Scientific Ideas of the Mayas."

Dr. Bridges first gave his audience some idea of the historical and geographical background of the Mayas, whose civilization reached its highest point in the 5th century but was falling into decadence by the time of the Spanish conquest. Their culture was expressed in architecture and sculpture, handicrafts, medicine and dentistry, and priestcraft which included the esoteric knowledge of writing, numbers, the calendar and observational astronomy. The chief sources of information are the inscriptions on their monuments and the codices. Unfortunately only three of their codices now exist, the rest having been burnt by order of Bishop Landa after the conquest.

Speaking of the science of numbers, Dr. Bridges pointed out that the Mayas were the first to invent the concept of zero and position value in mathematics. In the Old World the zero was invented by the Hindus between the 6th and 8th centuries and brought to Europe by the Arabs but it was not adopted by our ancestors until the 15th century, whereas there is evidence that the Mayan system was well developed three or four centuries B.C. The Mayas used a vigesimal, instead of the decimal, system, the value of their signs increasing by multiples of twenty. They used only three symbols—a dot for 1, a bar for 5, and a symbol representing an empty shell for zero—and their numbers were written in a vertical column instead of a horizontal line, the symbol at the bottom having the lowest value.

Though it seemed very complicated when Dr. Bridges first began to explain it, the construction of the Mayan calendar is really quite simple and logical. Corresponding to our days of the week were twenty days, each with a different name. The days were also numbered from 1 to 13, and as the numbers ran out before the names did, the same combination of names and numbers occurred only once in a period of 260 days. This period was called the Tzolkin. The year was divided into 18 periods, or "Uinals," of 20 days each, plus 5 "unlucky" days at the end of the year to make the total of 365 days. The days of each Uinal were numbered from zero to 19, only elapsed time being counted. Each Uinal had its identifying glyph, and so the same combination of signs and numbers for both the Tzolkin and the solar year occurred only once in 18,980 days, or 52 years. This period is called by anthropologists the "calendar round." In addition there was the "long count," counting the time in days from the beginning of the Mayan era, by means of Tuns, Katuns, Bactuns and Pictuns, one Tun equalling 20 Uinals, and so on.

The Mayas knew the average period of the moon's revolution. There are records made at Palenque of 81 lunations in 2392 days (average 29.53086 days) and at Copan of 149 lunations in 4400 days (average 29.5302) and there is evidence of an astronomical conference between the two cities regarding this difference in their observations. (The average lunation is now known to be 29.53059 days.) They were also aware of the length of the tropical year. The insertion of an extra day for leap-year would upset their whole calendar system, but their inscriptions of dates bear corrections in a second series. Palenque's records average out at 365.2428 days and Copan's at 365.2420 days, and there was another controversy on this point. It is interesting to note that the Julian calendar, in

use at the time of the conquest, was based on 365. 25 days,and subsequently had to be adjusted by the Gregorian calendar of 365.2425 days. The Mayas also made elaborate observations of Venus, and the Dresden Codex, one of the three to escape destruction, contains tables of solar and lunar eclipses which they were able to predict with great accuracy. One problem confronting the anthropolgist is the co-relation of Mayan dates with ours, for after the third Bactun of the tenth Pictun, the Mayas stopped counting any higher than Katuns.

Dr. Bridges illustrated his lecture with numerous slides of their architecture and sculpture and the glyphs found in their inscriptions.

ISABEL K. WILLIAMSON, *Recording Secretary.*

AT VICTORIA

January 12, 1944.—The meeting opened at 8.15 p.m. with the President, Mr. O. M. Prentice, in the chair. Four new members were welcomed, Mr. B. Warfield, Lieut. C. C. Kernahan, Mr. Ian Stewart, Mr. G. A. C. Davis. The treasurer reported that so far $321 had been raised for the Brydon Observatory fund.

Dr. C. S. Beals of the Dominion Astrophysical Observatory was introduced by Mr. Prentice. His subject, "Instruments for Analyzing Star Light," proved a very interesting and instructive one. Dr. Beals illustrated his lecture by many slides, starting with a picture of the early sextant of Tycho Brahe used for measuring the angular distance between stars. The greatest advance was the invention of the telescope by Galileo. One of the main defects of the refractor was the lack of achromatism, which Newton overcame by the invention of the reflecting telescope. Then the achromatic lens was made and a picture of the largest refractor, the 40-inch telescope at Yerkes Observatory, was shown, and also the first important modern reflector, the 60-inch at Mount Wilson, which was the inspiration of the beautifully designed 72-inch reflector of the Dominion Astrophysical Observatory.

Then by drawings, Dr. Beals described the function of the spectrograph and the course of light through it. The Coudé spectrograph has a permanently mounted spectrograph so the instrument can be larger and thus a higher dispersion obtained. Pictures were shown of the new Littrow spectrograph and camera of the Dominion Astrophysical Observatory, by which one can effectively have six prisms to obtain high dispersions. Really the light is sent through three prisms and then by a flat mirror reflected back through three prisms again.

The microphotometer is an instrument for determining the degree of blackening of the photographic plate, and from that by use of an intensitometer the intensities of the lines are readily obtained.

Mr. Peters gave a hearty vote of thanks to the speaker and Dr. R. M. Petrie drew the attention of the audience to the occultation of Jupiter Jan. 13 at 4 a.m. After the lecture the members were much interested in the demonstrations of other instruments—telescopes, planimeter and projection measuring engine—by R. M. Petrie and W. H. Stilwell. The meeting adjourned at 10 p.m.

February 9, 1944.—The meeting opened at 8.15 p.m. with Mr. M. Trueman presiding, in the absence of Mr. O. M. Prentice. Two new members were welcomed, Miss Jean McDonald and Mrs. A. M. Carter.

The speaker was Dr. K. O. Wright of the Dominion Astrophysical Observatory, who is this year on loan to University of British Columbia as a lecturer in Physics. His subject was "The Earth, Past, Present and Future." It was based on the recent book by George Gamow, "The Biography of the Earth." Four theories of the origin of the earth two billion years ago were presented. The accepted one at present is that of Jeans, that another star approached the sun and the outer layers of the sun were pulled away, producing a filament, which then broke up into the planets. A proof of the age of the earth is obtained from the length of time required for radio-active materials, such as uranium, to turn into lead as it is found on the earth today.

The inner core of the earth is believed to be liquid at a temperature of 5000°C. One proof of this is that the transverse (shear) waves of an earthquake sometimes cannot be observed at the seismograph station. They cannot pass through the liquid centre of the earth. Around the central core is a plastic layer. The outer crust is made up of a basalt layer and then a granite one. One theory strongly presented by Gamow is that the moon originated from what is now the Pacific ocean, breaking away by the phenomenon of resonance.

Dr. Wright described the manner in which mountains were formed by contraction of the solid crust when it lost the continuous flow of heat from the centre. Great pressures are set up and the granite parts of the surface are pushed up. He mentioned the fact that there have been at least five different geological ages.

Many interesting questions were raised and Dr. John Stevenson proposed a vote of thanks to the speaker. The meeting adjourned at 10 p.m.

March 8, 1944.—Mr. O. M. Prentice called the meeting to order at 8.15 p.m. Miss Y. Langworthy, librarian, gave a report on six new books added to the library.

The speaker, Dr. Wm. Petrie of the Physics Department, University of British Columbia, chose for his subject "The Nature of the Galaxies." Starting with our own galactic system, which contains 200 billion stars and has a diameter of 100,000 light-years, he showed many slides illustrating the characteristics of a galaxy. It is composed of equal masses of stars and dust and gas. The stars form two types of clusters, open clusters, which have no definite shape and may contain from six to thousands of stars, and the globular clusters which are spherical in shape. There are 100 of them known. They contain an average of 50,000 stars. The dust and gas in the galaxy may be in the form of bright nebulae or dark nebulae. The Milky Way is divided into two parts by dark nebulae. Planetary nebulae are made up of stars surrounded by a shell of gas.

Leaving our own galaxy, Dr. Petrie spoke of the external galaxies which may be elliptical, irregular, as the Magellanic clouds (our nearest galaxy), or spiral, which have a central nucleus and long spiral arms. The nebula in Andromeda is the only spiral visible to the naked eye.

Dr. Petrie then described briefly the methods of finding the distances of galaxies. The nearer ones can be resolved into separate stars, some of which are Cepheid variables, whose absolute magnitude varies as the period of their light variation. By comparing the apparent brightness with the true brightness the distance can be calculated. For the more distant galaxies, statistical methods must be used. There are 100 million within reach of the 100-inch telescope.

The motion of the galaxies is determined by the shift in spectral lines at different distances from the centre. In one type of velocity curve the velocity of rotation is directly proportional to the distance from the centre, then the velocity begins to fall off with distance from the centre, showing that the density is constant in the centre and then decreases. However, some velocity curves do not follow this pattern.

The mass of the galaxies is obtained, assuming the galaxy is stable, by the formula

G(gravitational const.) $\times$ Mass/R^2 = V^2(rot'n. vel.)/R(dist. from centre)

The average galaxy contains two billion stars, so our own galactic system is a giant one.

Many interesting questions were asked and Lieut. Comdr. McDonald expressed the tanks of the audience to the speaker.

April 12, 1944.—Mr. O. M. Prentice called the meeting to order at 8.15 p.m. He announced that sufficient money had been raised to make a payment on the Observatory being purchased by the Society from Mr. Brydon.

Mr. W. R. Hobday, past president of the Society and director of the telescope-making section, spoke on "The Solar Family." He used a unique illustration of the comparative sizes and distances from the sun of the nine planets, designating them as different sized balls placed at different locations in the vicinity of Victoria. He mentioned a distinguishing characteristic of each. Mercury always has one face to the sun; Venus is the brightest object in the sky, often seen in daylight; the earth has a very large satellite as compared with its own size; Mars' polar caps increase and decrease with the seasons; Jupiter is the largest planet and its four largest satellites are intersting to observe; Saturn has a unique ring system; Uranus' rotation on its axis is almost in line with the plane of its revolution around the sun. Neptune and Pluto were discovered by mathematical means.

Mr. Hobday concluded with a brief reference to the other members of the solar family, comets and meteors. Comdr. Hughes thanked the speaker for his very well presented talk.

E. C. STILWELL, *Recorder.*

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